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Simulation of Reservoir Systems with HEC-5 on a Personal Computer

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Simulation of Reservoir Systems with HEC-5 on a Personal Computer

Description and User Guidance

May 1990

US Army Corps of Engineers
Water Resources Support Center
Hydrologic Engineering Center
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Chapter 1

Introduction

A package of computer programs has been assembled to simulate the operation of reservoirs and display results on a personal computer (PC). The package uses HEC-5, "Simulation of Conservation and Flood Control Systems" as the basic computational tool. The HEC-5 User's Manual, and the Exhibit 8 Input Description provide detailed information on the use of HEC-5. This document provides general installation information and describes each component of the PC package.

1.1 Program Development

The HEC-5 computer program was developed from 1972 through 1988 at Hydrologic Engineering Center (HEC) by Bill S. Eichert. The original version utilized large storage, high speed mainframe computers. Later versions of the program have added numerous supplemental capabilities, and a new version has been issued about once per year since 1979. The scope of the program has changed from a simple flood control system to a highly complex multi-purpose, multi-reservoir, multi-flood simulation tool.

Modernization of the source code began in 1984. A part of this process included conversion to meet the ANSI FORTRAN-77 standard. The program was also divided into smaller logical subroutines, or modules. This modernization effort assisted in the conversion to the PC in 1987. The 1987 PC version was heavily overlayed to fit into the size and storage constraints imposed by the PC MS-DOS environment. An overlay memory caching scheme was also implemented to enhance program performance.

In 1987, HEC-5 was combined with a package of utility programs to merge all the necessary tools to accomplish the simulation and analysis of reservoir system operation on a PC.

Since the 1987 release, refinements and additional capabilities to the programs have continued. The 1989 extended memory version of HEC-5 implements the mainframe version, retaining both the full dimensions and capabilities. The overlayed version has full capabilities but reduced dimensions in order to operate in a DOS 640Kb environment. Additionally, improvements have been made to each of the other programs in the PC package.

1.2 Overview of the HEC-5 Package

The basic steps in simulating a reservoir operation include:

(1) Gather physical data,
(2) Select or develop time series (i.e., flow) data,
(3) Develop operational criteria,
(4) Develop data file representing the reservoir system to be studied,
(5) Check the data file for proper format and data errors,
(6) Simulate the operation of the reservoir system,
(7) Review and evaluate system operation,
(8) Modify input data if necessary, and
(9) Display results graphically

The computational process is illustrated in Figure 1. The programs provided with the HEC-5 package provide the necessary tools to accomplish steps 4-9 on a PC. A menu program, MENU5, has been developed to provide program users convenient access to the HEC-5 package of programs and related files. The menu, described in Chapter 3, eliminates repeated typing of program and file names in order to use the programs in the package.

Text editors can be used to create and modify an input data file for the HEC-5 program. The Corps' editor, COED, has been developed with some features specifically designed around the HEC format for computer program input. COED will place the input data in the format expected for HEC-5 as the data file is created or edited. It also has an on-line variable "help" file to assist users in the preparation of HEC-5 input files. Chapter 4 provides information on creating and editing HEC-5 input files.

Checking an HEC-5 data input file for errors is facilitated with the CKHEC5 computer program. The program provides tests for proper input sequence, format and data ranges. Running the input data file with CKHEC5 is recommended to assist in locating input errors. Chapter 5 describes the CKHEC5 program, the types of error messages, and the typical corrections required.

The many capabilities in HEC-5 can be used to solve a variety of reservoir operation problems. Chapter 6 provides information on running HEC-5 on a PC.

Once the HEC-5 program has been executed, the results can be reviewed in several ways. Chapter 7 describes the HEC-5 output and gives some guidelines for output review. Input can be easily modified with the MOD5 program which is described in Chapter 8. Finally, graphical results can be created with the DSPLAY utility program, the subject of Chapter 9.

1.3 Program Documentation

The primary documentation of the HEC-5 program is the User's Manual. The manual provides a complete description of the HEC-5 program capabilities, theoretical basis for computations, and examples of program output. Exhibit 8 of the User's Manual is a separate document describing program input. A careful review of the User's Manual should be made before using the computer program. Programs INFIVE, INCARD, CKHEC5, MOD5, DSSUTL and DSPLAY each have their own user's manual. The implementation for these programs is described in this document. Supplemental information is available through the following HEC publications:

Installation Instructions for Microcomputer Version of the HEC-5 Package of Programs

Appendix on Water Quality Analysis

IHD Volume 7, Flood Control by Reservoirs

IHD Volume 8, Reservoir Yield

IHD Volume 9, Reservoir System Analysis for Conservation

Training Document 12, Application of the HEC-5 Hydropower Routines

Training Document 20, Water Supply Simulation Using HEC-5

Training Document 24, Water Quality Modeling of Reservoir System Operations Using HEC-5

Training Document 27, Flood Control Simulation Using HEC-5 (Draft)

Training Document 28, Hydropower Simulation Using HEC-5 (Draft)

Technical Paper No. 101, Use of Computer Program HEC-5 for Water Supply Analysis

Technical Paper No. 119, Multi-purpose, Multi-reservoir Simulation on a PC

Technical Paper No. 123, Developing and Managing a Comprehensive Reservoir Analysis Model

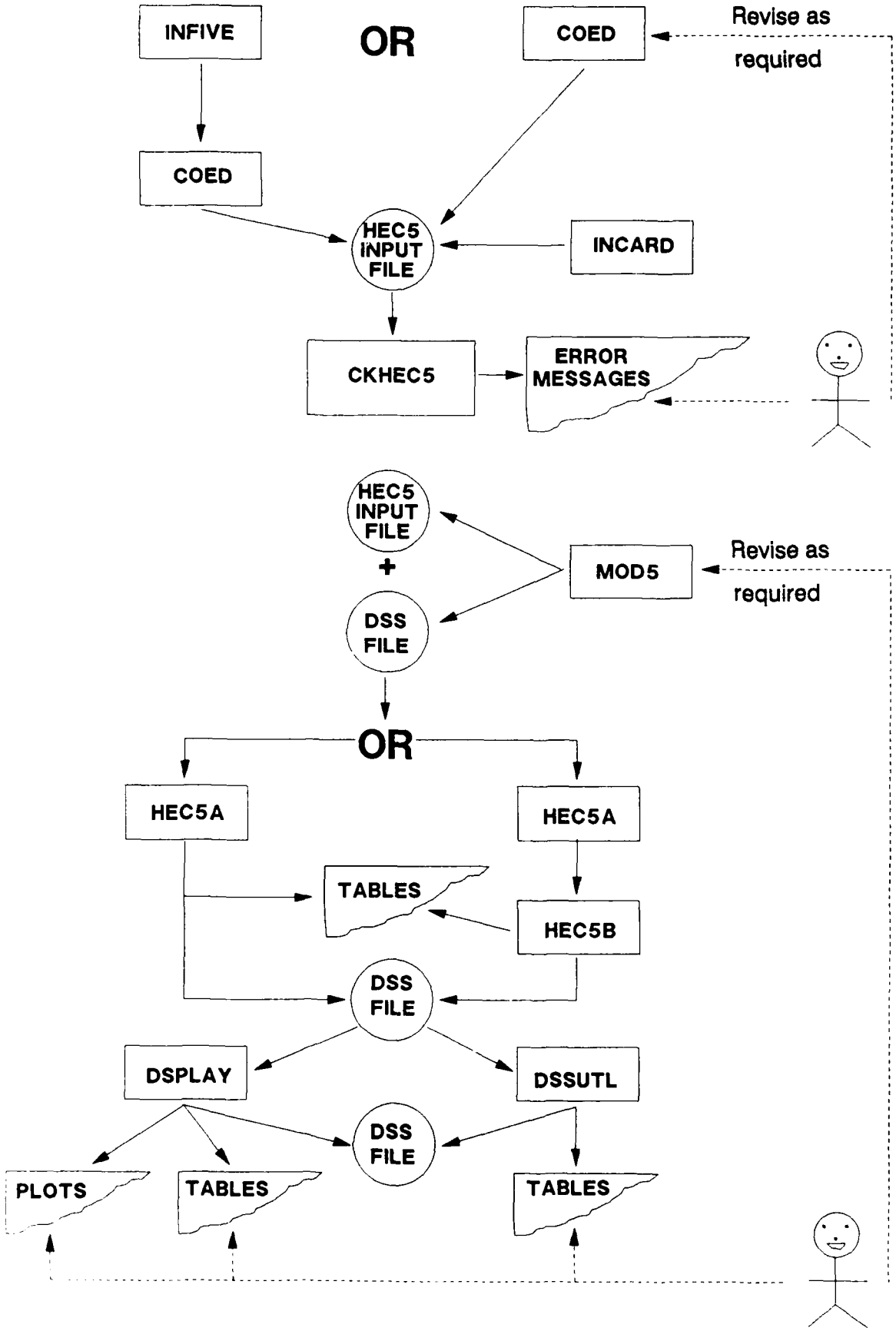

Figure 1. Computational Process of HEC-5 Package of Programs

The supplemental material, as well as other HEC publications, are listed in the Publication Catalog along with prices and ordering information. This free catalog is available from:

Hydrologic Engineering Center
Attn: Training Division
609 Second Street
Davis, CA 95616-4687

HEC provides training in HEC-5 in a two week course devoted to Reservoir System Analysis which is presented every other year, generally in early December. HEC-5 instruction is also presented in the Real-Time Water Control course and in special Corps District Workshops.

For those unable to attend a course, there are video tapes of most lectures given in HEC training courses on HEC-5. The tapes are distributed by a contractor, which may vary from year to year. A Video Tape Catalog with ordering information is available from HEC at no charge.

1.4 Program Distribution

HEC distributes its programs to Corps of Engineers offices and other federal agencies. Program support is also available to Corps offices and other federal agencies. All other public agencies, private firms, and international groups can acquire the programs through private distributors or the National Technical Information Services (NTIS). A referral list of distributors is available from HEC.

A free Computer Program Catalog is available from HEC. The catalog provides a description of all available computer programs as well as ordering and program support information.

1.5 Acknowledgements

This document was prepared under contract by Teresa H. Bowen, Bowen Engineering. Richard Hayes, Marilyn Hurst and Vern Bonner were major contributors to the material presented in the document.

The HEC-5 computer program was developed by Bill S. Eichert, former director of HEC. The PC version was created by Carl Franke and Marilyn Hurst. Richard Hayes was the engineer in charge of the program and provided much direction and support.

The HEC-5 auxilary programs, INFIVE, INCARD, CKHEC5, and MOD5 were developed by Bill Eichert with assistance from Al Onodera and Marilyn Hurst.

The HEC Data Storage System (HECDSS), the data management utility (DSSUTL), and the graphic component of DSS (DSPLAY), were developed by Al Montalvo, Bill Charley, and Art Pabst.

The menu program, MENU5, was developed by Keith B. Knight and Marilyn Hurst. It provides convenient access to the HEC-5 package and the utilities; LIST, PROUT, and COED.

The PC version of COED, with full-screen edit capability, was developed at HEC by Art Pabst and Bill Charley from the command-line editor (in use on the Harris Computers in the Corps of Engineers since 1980). Many of the features of the new PC version are also available on the new Harris computer version.

The LIST program is a public domain utility written by Vernon D. Buerg, AAI Systems, Inc. The program is presently distributed as share-ware with a request for a gift to support development. PROUT is a program developed at HEC by Al Montalvo for the purpose of directing output files to the printer with carriage control invoked.

Chapter 2

Loading Programs on Your Computer

Complete instructions for the installation of the HEC-5 programs are provided in a separate document entitled "Installation Instructions for Microcomputer Version of the HEC-5 Package of Programs" which is distributed with the HEC-5 Package. Important aspects of the installation instructions are briefly summarized in this chapter and include hardware and system requirements for two configurations of the HEC-5 package and program installation (including creation of recommended directories).

2.1 Computer Hardware and System Requirements

IMPORTANT

A hard disk is required to run HEC-5 on all PC systems.

NOTE: GSS DEVICE DRIVERS REQUIRED

The HECDSS DSPLAY graphics program included with the HEC-5 package of programs requires GSS device drivers to create graphical displays. Device drivers are software packages for specific plotters, printers and graphics adapters.

GSS device drivers for non-Corps Offices may be obtained from GSS (Graphic Software Systems, Inc., 9590 S.W. Gemini Drive, Beaverton, OR 97005). Device drivers for Corps of Engineers offices may be obtained from HEC (Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616)

The 1989 version of HEC-5 (updated January 1990) is available in the following two configurations:

1. Overlayed PC version for IBM PC/XT or compatibles. The minimum system requirements are as follows:

640Kb (or more) of main memory

MS DOS 3.0 (or later) operating system

360Kb, 5-1/4 inch floppy disk drive

10Mb (or larger) hard disk
(A minimum of 8 Mb of storage should be available on the hard disk when the program is installed)

Math Coprocessor (8087, 80287 or 80387 chip)

One Mb or more of EXTENDED memory should improve execution speed by 3 to ·, times.

2. Extended Memory PC version. The minimum system requirements are as follows:

IBM or Compaq compatible 80386 Microcomputers

640 Kb (or more) of main memory

3 Mb of EXTENDED memory

MS DOS 3.0 (or later) operating system

20Mb (or larger) hard disk
(A minimum of 10 Mb of storage should be available on the hard disk when the program is installed)

1.2 Mb, 5-1/4 inch floppy disk drive

Math Coprocessor (80387 chip)

The Extended Memory PC version of HEC-5 incorporates the OS/386 "DOS Extender" operating system developed by Ergo, Inc. (formerly Eclipse Computing Solutions). Information on the OS/386 operating system may be obtained from Ergo, Inc., Building 400, One Kindall Square, Cambridge, MA 02139.

2.2 Program Installation

The installation of the software that comprises the HEC-5 Package of Programs is accomplished with an interactive procedure (INSTALL5) which is included with the HEC-5 diskettes. INSTALL5 allows the user to specify the hard disk (C: or D:) on which the software is to be installed, as well as the selection of the groups of programs or example data sets to be installed. It additionally creates the recommended directories for program installation.

The directories which are created by INSTALL5 are consistent with the recommended directory configuration for other HEC programs (such as HEC-1 and HEC-2). Figure 2 shows a typical configuration of how a PC hard disk is organized when using HEC application programs. The contents shown for directories labeled \HECEXE and \HECEXE\SUP reflect files that are installed for the "overlayed" PC version of the HEC-5 package of programs.

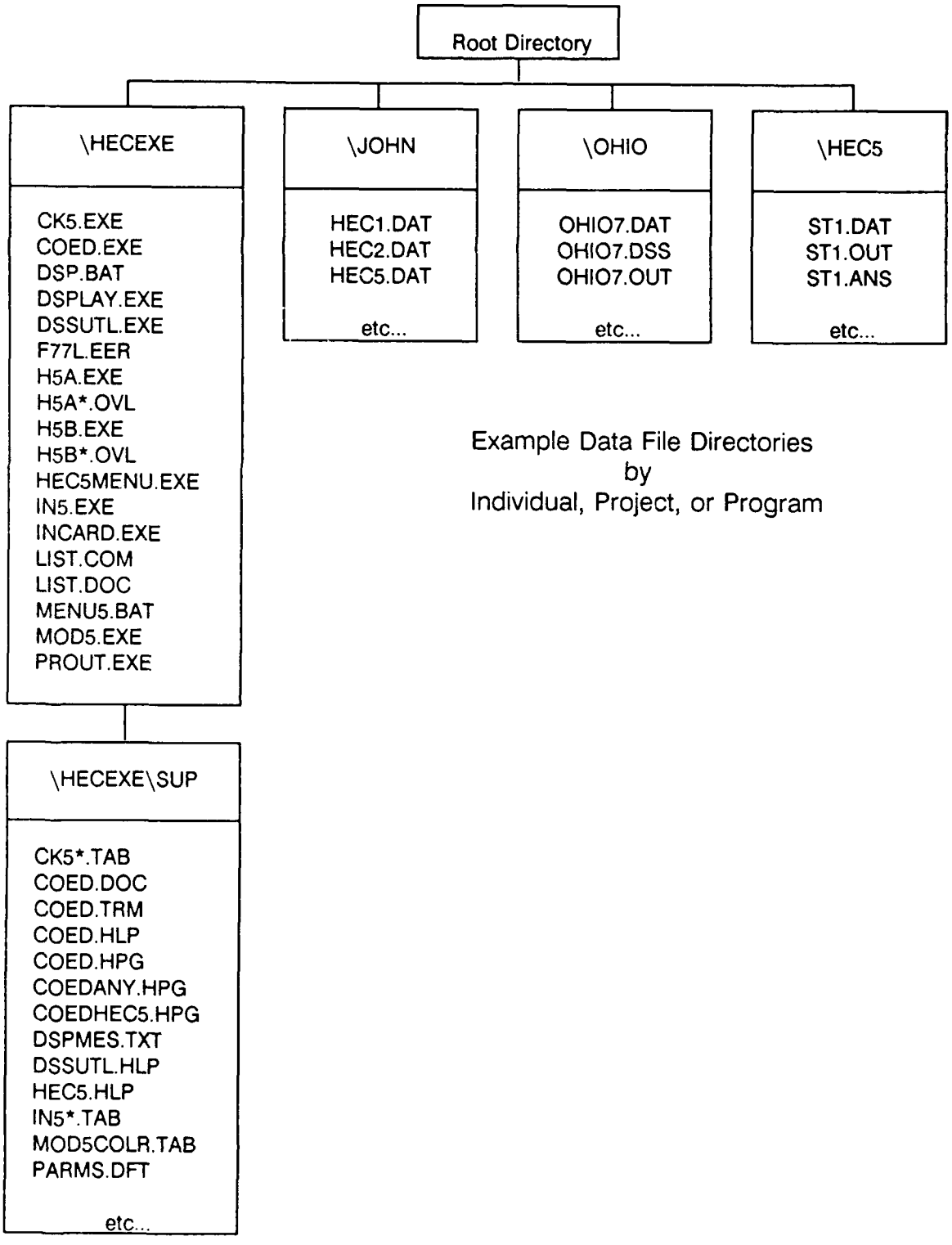

Figure 2. PC Hard Disk Organization Using HEC Application Programs

Chapter 3

HEC-5 Package Menu Program

3.1 Purpose of MENU5 Program

A menu program, MENU5, has been created to aid the user in operating HEC-5 and auxiliary programs. The menu system provides the capability to create and edit input files; execute the HEC-5 program; and to display output conveniently to the screen or the printer. All of the programs in the package can operate independently without the menu; however, the menu makes it more convenient to define and transfer file names among the various programs in the package. The following provides a description of the menu operation.

3.2 Program Set Up

The executable programs in the HEC-5 package are stored in a directory \HECEXE, along with the menu batch file (MENU5.BAT). The DOS PATH command is used to specify which directories are to be searched for commands or batch files. Therefore, \HECEXE should be included on the PATH command. The PATH command is included in the AUTOEXEC.BAT file so that it automatically enters the command when you boot the system. Refer to your DOS Manual for information of the PATH command and the AUTOEXEC.BAT file.

The data files for HEC-5 should be developed in a separate working directory (e.g., \HEC5). The test data can be copied into this directory if you want to run the Standard Tests. Initiation of the MENU5 program should occur from this directory; therefore, all input, output, and scratch files are in this directory.

3.3 Program Operation

The HEC-5 programs in the \HECEXE directory can be called while operating in any directory because the PATH includes \HECEXE. All the programs in the HEC-5 package can be executed from this menu, as well as defining input and output file names. To operate the HEC-5 package, change into the Working Directory (e.g.,\HEC-5) and execute the MENU5 program.

```
C:> CD \HEC5

C:> MENU5
```

You must execute the menu system through this batch file (MENU5.BAT) or the programs will not function correctly. The HEC-5 Package Menu should appear on the screen as shown in Figure 3. As you can see, there are five choices with the first choice being highlighted. The status line is also highlighted at the bottom of the screen. This status line is used to direct the user on how to proceed at any point. The background and text colors can be changed for color monitors by pressing the **F9** and **F10** keys, respectively. The program saves the selected colors in the PARMS.DFT file.

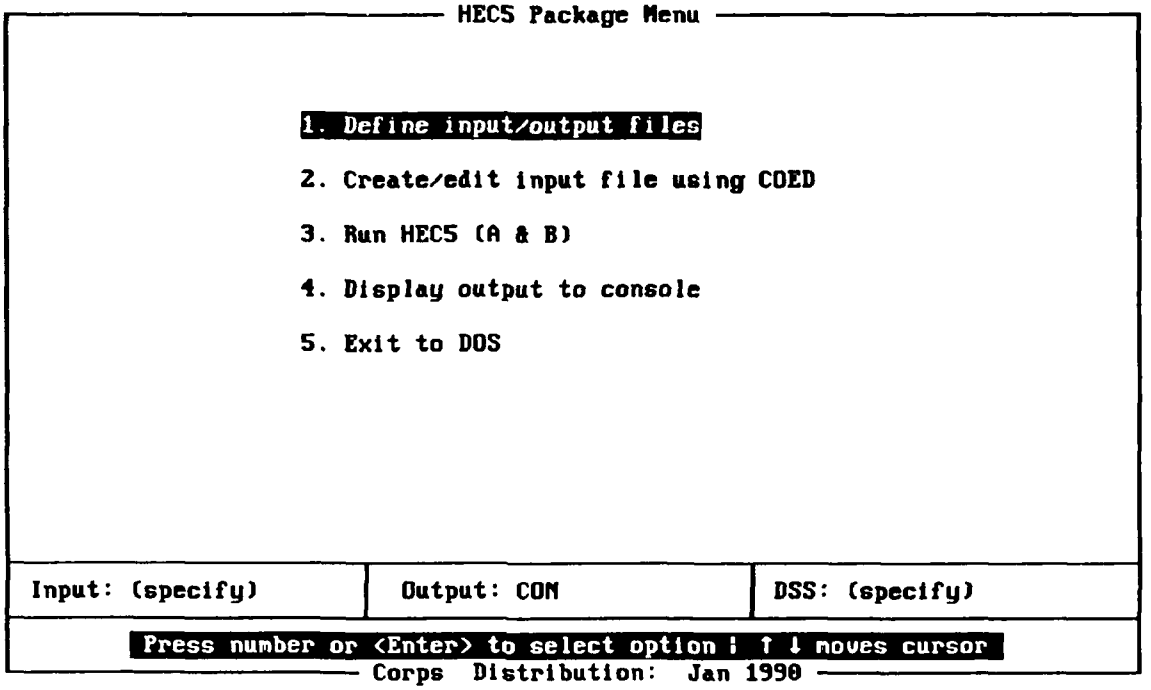

Figure 3. *HEC-5 Package Menu, MENU5*

In general, the user operates the menu by using the cursor arrow keys to move to the desired option and presses the **<ENTER>** key to execute that option. Another way to execute an option is to press the number of the desired function. Each of the five options are discussed below.

1. OPTION 1: Define input/output files

This option is used to define the target input and output file names that are used when executing HEC-5, and the support programs. When this option is selected, a pop-up menu appears as shown in Figure 4.

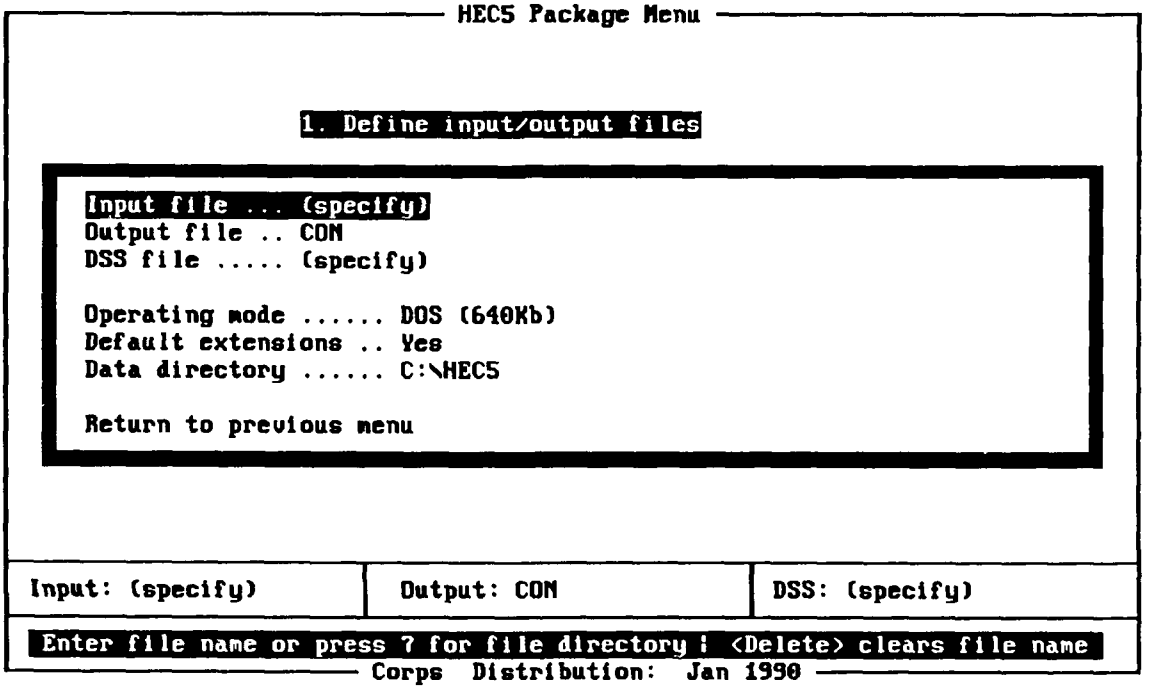

Figure 4. Define Input/Output Files Menu

The menu is set up to use the following default extensions for HEC-5 files:

.DAT for input data files
.OUT for output files
.DSS for HEC-DSS files

The automatic extension feature can be turned off by moving the cursor to **Default extensions** and pressing the Space Bar to toggle the choice to **NO.**

The input, output and HEC-DSS filenames can be entered directly , or a **<?>** can be entered to get a listing of the files available in the current data directory as shown in Figure 5. The default extension option, described previously, limits the file listing to those files with the appropriate assumed extension, e.g., **.DAT** for data files. The cursor keys can be used to highlight the desired file, and pressing **<ENTER>** selects the highlighted file.

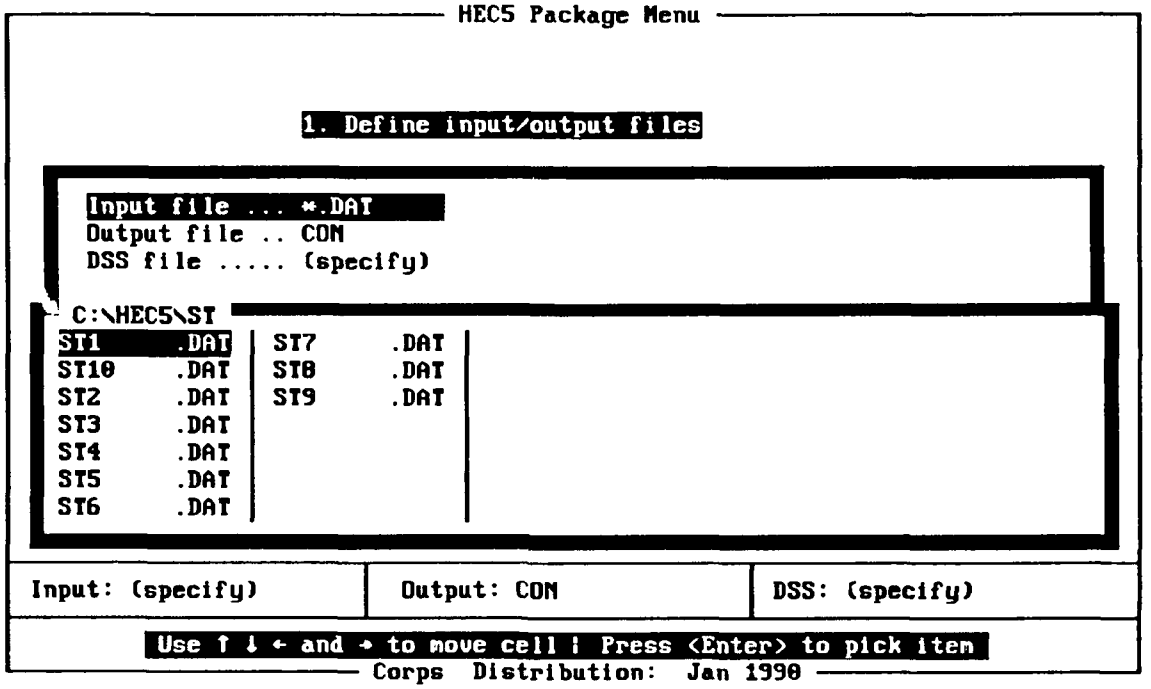

Figure 5. MENU5 Data File Listing

For example, to use Standard Test 1, highlight **ST1.DAT**, press the **<ENTER>** key, and the resulting screen display should appear as shown in Figure 6.

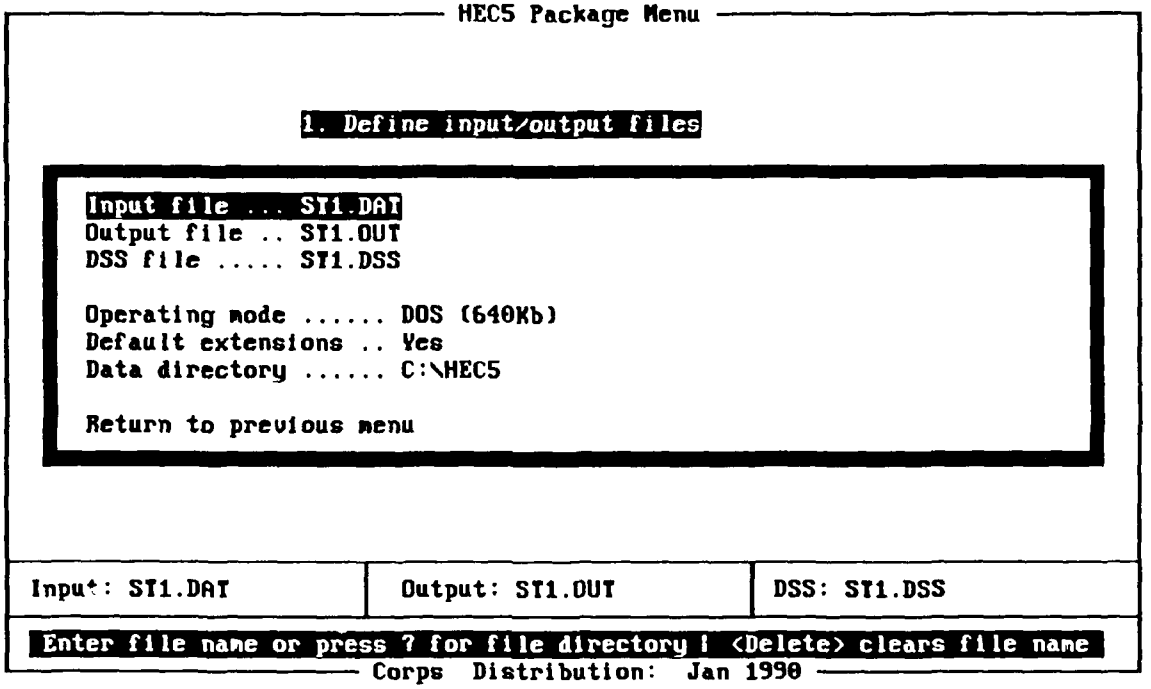

Figure 6. Define Input/Output Files Using Standard Test 1

When all the file names have been defined, move the cursor to the **Return to previous menu** option and press <**ENTER**>. However, with Default extensions option on, the cursor automatically moves to this option after the input file name is defined and you need only press <**ENTER**>. This returns you to the main MENU5 menu. Note that at the bottom of the screen there is a line that displays the names of the current input, output and DSS files that are being used.

2. OPTION 2: Create/edit input file

This option is used to create an input file or to edit an existing input file to be used by HEC-5. There are four programs available under this menu option: COED, INFIVE, MOD5, and INCARD. This option will only function if you have also installed these programs on your system. To select a program using this option, highlight Option 2 by using the cursor key. The space bar can now be used to toggle between the programs. When the desired program is seen, press <**ENTER**> to proceed. COED and INFIVE are used for input file creation, while both COED and MOD5 may be used to edit an existing input file. INCARD is used to convert inflow data sets (HEC-5 BF and IN records) from one time interval to another. The following summarizes execution of each program available in Option 2:

Executing the COED program allows you to create a new file or edit an existing file. To execute COED, use the space bar as a toggle switch until COED appears, then press <**ENTER**>. To check the "filename" before calling COED with the defined input file name, the MENU5 program will echo:

Edit "filename" (y/n)?

Enter <**y**> or press <**ENTER**> to proceed. Enter <**n**> if you want to change the "filename"; then enter the desired file name to edit.

Selecting this option calls COED with the defined input file name, and the file is shown in full screen mode. When COED is executed though the menu system, the HEC-5 help file is also automatically loaded. For help in using COED, press the **F1** key or refer to the COED User's Manual. For help with specific variables while in the full screen mode, press **ALT F1**. When you have completed the edit session, exit COED (usually with the SAVE or FILE option).

If program INFIVE is executed, the program allows you to name the input file created at the end of the interactive session. Therefore, the input file need not be previously defined. The file can then be edited with COED.

Program MOD5 is used to modify an existing input file. To execute MOD5, press the space bar until MOD5 appears and press <**ENTER**>. The interactive program guides you through operational changes and saves the revised file under the current output file name. However, upon exiting MOD5, you can specify the filename for the modified file.

Program INCARD is used to change the time intervals for time series data. The input required is the time series data portion of an HEC-5 input file (BF through ER records). INCARD can be called by pressing <**ENTER**> when the program name appears.

With completion of any program in the package, the screen will echo:

Strike a key when ready...

This allows you to see if there are any error messages written to the screen from the current program operation. Pressing any key returns you to the main HEC-5 Package MENU.

3. OPTION 3: Run HEC-5

This option executes the HEC-5 program, as well as programs CKHEC5, DSPLAY, and DSSUTL. The input and output filenames, defined under Option 1 is passed to the HEC-5 program. The program selection is made by moving the cursor to this line and pressing the space bar, until the desired program is displayed:

Run HEC5 (A & B)
Run HEC5 (interactive)
Run HEC5 (A only)
Run CKHEC5
Run DSPLAY
Run DSSUTL

The three HEC-5 execution modes include: "**Run HEC5 (A & B)**", which executes both the operations (HEC5A) and output (HEC5B) portions of HEC-5; "**Run HEC5 (interactive)**", which provides interactive selection of output during the execution of HEC5A; and "**Run HEC5 (A only)**", which executes only the operations component (HEC5A). The HEC-5 data checking program may be selected for execution by "toggling" through the choices until "**Run CKHEC5**" is highlighted. The HECDSS programs are also selected by "toggling" through the program names until "**Run DSPLAY**" or "**Run DSSUTL**" are highlighted. After selecting the program which you wish to execute, initiate execution by pressing the <**ENTER**> key.

It is good practice to first execute Program CKHEC5 to check an input file that has been created or edited. Press the space bar until CKHEC5 is displayed, and then press <**ENTER**>. The defined input file is processed with CKHEC5, and the output is written to a file with .CK5 extension. The LIST program is invoked automatically upon completion of the CKHEC5 execution. This allows you to view the messages that the CKHEC5 program generates. To exit the LIST program press the <**X**> key. The input file can then be edited by going back to option 2, or if no changes are needed, HEC-5 can now be executed from this menu by pressing the <**ENTER**> key when the desired program is highlighted. When the program is finished executing you should review the output file using option 4.

4. OPTION 4: Display output to console

This option is used to display output to the console or to the printer. Program LIST is called with the output file name to provide console display. Use the cursor keys to move through the file. The <**End**> and <**Home**> keys are convenient for moving to the bottom or beginning of the file. Press <**F1**> to see the LIST commands. Press the <**X**> key to exit the LIST program. To switch from console to printer, press the space bar while option 4 is highlighted. Program PROUT is then called to send output to the printer with carriage controls. PROUT will print with either 80- or 132-character length. The printer must first be set to normal or condensed print mode. After the file has finished printing, control is given back to the main HEC-5 Package Menu.

5. OPTION 5: Exit to DOS

Selecting this option will exit you from the MENU5 program and return control to DOS. Press <**5**> or move the cursor to line **5. Exit to DOS** and press <**ENTER**>. The defined file names and screen colors are saved in the file named PARMS.DFT.

Chapter 4

Creating an Input Data File

The HEC-5 program is a batch program. That means the necessary data for the program is provided as INPUT at program execution and the program processes the entire job to completion. The program user does not interact with the program during execution, except for reviewing simulation results (as described in Section 6.3). This section describes the sequence of an HEC-5 computation process, the input data format, and the basic steps for creating and storing an input data file.

4.1 Sequence of HEC-5 Computations

Any reservoir system configuration may be used as long as dimension limits are not exceeded for number of reservoirs, number of control points, number of diversions, and number of power plants. The system configuration is specified by routing reaches in downstream sequential order of control points. The program operates the system spatially. Reservoir release decisions are made in the sequential order of input data, from upstream to downstream until all reservoirs have operated for their appropriate downstream locations. The system is operated in this fashion for every time period in the hydrologic data, taking into consideration forecast periods, contingency allowances, and routing effects between control points.

4.2 Input Data File Format

The structure of the HEC-5 input data file can be seen by reviewing any of the test data sets provided with the program. The detailed input description is provided in Exhibit 8 of the User's Manual.

The format for the HEC-5 data is a "standard" HEC format. The concept is based on the 80-column data record associated with batch input. The first two columns are used for the record identifier (ID); the program reads and sorts through the data based on the record ID. Each record is divided into ten fields of eight columns each. However, a variable in field one may only occupy record columns 3 through 8 because the record ID is in columns 1 and 2. The HEC-5 User's Manual, and this text, refer to the individual records by their ID and the variable location of the record by the field number (1 through 10).

Data entry into fields requires careful counting of columns to ensure that the data are located in the correct fields. If a value is entered across a boundary (column) between fields, the program reads part of the value as one variable and the remaining portion as the value for the variable in the next field.

There are several options available to assist the program user in entering data into fields without counting record columns to space data entries into the correct fields. Program INFIVE creates an input data file and enters data into respective fields through a series of questions and answers. The Corps interactive edit program, COED, automatically places input data into standard (fields of eight) format. COED also provides on-screen help features that enhance the data entry function of the editor. The use of COED and INFIVE is described in the following sections.

4.3 File Creation and Storing

Basically, the input is made up of the Title records, the Job records that define reservoir levels and program options, physical and operational data describing reservoirs and control points, and hydrologic data. Refer to Exhibit 8 of the User's Manual for input descriptions. A Functional Use Index in Exhibit 8 shows the records to use for various program options.

Physical and operational data begins with the Title records and ends with the ED record. The hydrologic data begins with the BF record and ends with the EJ record for each succeeding event. An ER record ends the input data file.

To create an input file, the editor program COED is executed along with an input file name. If the file does not exist, the file is created and is then available for data entry. The data are entered, starting with the first record, and sequentially entered through the required data set for the reservoir system. Program INFIVE can aid in setting up the required sequence of records for a given system.

The input data file is saved with the appropriate COED command. Usually, the FILE command can be invoked by pressing the **<ALT> <F10>** keys. While in full screen mode, a single COED command can be entered for the **E>** prompt, which can be obtained by pressing the **<F9>** key. Pressing **<F10>** changes COED into the Command mode of operation. Entering **<FS>** takes COED back to the full screen mode.

When complete, exit the text editor, and the input data file is now available to use with the various programs. Before running HEC-5 with your data, it is strongly recommended that the input data file be checked with **CKHEC5.** Chapter 5 describes how to check the input data file.

4.4 Output Control

There are various options available in HEC-5 to control the type and amount of simulation output. Normal sequential output (refer to J3 record, field 1) contains all computed output variables and is tabulated by control point, by variable and by time period. Because normal sequential output can be quite voluminous, it is not recommended for simulations with more than a few control points. Also available through the J3.1 output control are various other output variables and summaries. The output error check (represented by 4) is recommended in all simulations.

The preferred output format for reviewing most systems is called "User Defined Output" and is used to create custom tables. J8 records are used to specify the variables to be included on the tables (see the HEC-5 User's Manual, Exhibit 8 for a complete description). Many output variables are available and appropriate variables can be requested for each control point. In addition, the sum of columns or the difference between two columns can be computed.

In order to properly review simulation results, several variables are recommended to be requested in every simulation. The variables are:

For reservoirs:	.09	Reservoir Inflow
	.10	Reservoir Outflow
	.11	Reservoir End of Period Storage
	.12	Reservoir Case
	.13	Reservoir End of Period Level
For non-reservoir control points:	.04	Regulated Flow
	.24	Incremental Local Flow

In addition to these variables which should be requested in every simulation, variables specific to the options used should be included. For example, power variables .15, .16, .23, .25, and .35 should be requested for reservoirs with hydropower plants in the system.

More information on how to review these output variables is contained in Chapter 7, Reviewing the HEC-5 Output File.

4.5 COED Application

When creating or editing an input file from MENU5, COED is the program that is used. Calling COED from MENU5 also includes two parameters: **FS** and **HP HEC5.** If you run COED separately, these parameters can be entered while in COED. Entering **HP HEC5** causes the HEC-5 input help file to be loaded that provides the tab settings for data entry as well as helpful information about the input variables for HEC-5. Entering **FS** puts you into the Full Screen working environment. COED operates as a command (line) editor (where you enter command codes and parameters) and also as a full screen editor (like a word processor). See the COED User's Manual for detailed documentation. Figure 7 shows an input data file in COED Full Screen edit mode (the recommended method of data entry) and also shows the input variables at the bottom of the screen.

```
TOF..
T1 SINGLE FLOOD CONTROL RES OPERATING FOR TWO C.P.              TEST 1
T2 USE DUMMY RES (5) FOR ROUTING REACH FOR NATURAL FLOWS   1982 INPUT FORMAT
T3                                                  EXAMPLE NO 1 FROM EXHIBIT 2
J1     0       1       3       2       3       1
J2    42       1    .167
J3   140                      -1                   1
J8 10.09   10.02   10.10   10.12   10.13    2.04    1.04    1.01    1.02    1.20
RL     5
RO
RS     2       0      10
RQ     2    10E5    10E5
CP     5   21000
ID HEAD WATER-DUMMY RES NAT ROUT
RT     5      10     1.1     3.2       0       0       0       1
RL    10                             50000
RO     2       2       1
RS     2       0   50000
RQ     2   21000   21000
CP    10   21000
ID RESERVOIR A  CP-10
RT    10       2     1.1     3.2       0
T1       First   Title   Card
Help=F1                                                  Col=1   Line=1
```

Figure 7. COED Input Data File

While in COED, with the HEC-5 Help file loaded in full screen edit mode, data entry will automatically use the first two columns for ID, the next 6 columns for Field 1, and the remaining 9 sets of 8 columns as Fields 2 through 10. With the cursor at the first column, enter any appropriate HEC-5 ID, (e.g., T1). The bottom of the screen displays a line of input information for the entered ID (e.g., **First Title Card** for T1). If the ID is not appropriate for HEC-5. you will get the message:

> > > > > **Card ID not recognized for HEC-5 input** < < < < < <

For Title record information the entire line is available to enter text; there are no fields. For data records, most fields represent variables, and the variables are shown on the line at the bottom of the screen. For example, enter **J1** and the variables for the J1 record are shown on the bottom line. Use the <**TAB**> key to move the cursor from field to field. The cursor automatically moves to the right of each field. Data entry also fills the field from the right. Therefore, the data are always right justified.

Data entry only affects the field the cursor is on. Therefore, inserting or deleting data in a field only works in the one field. If you continue to enter data in a field, the previously entered data is displaced to the left until it is moved completely out of the field. Use the <**TAB**> key, or a cursor key, to move to another field. Use the <**SHIFT**> <**TAB**> key to move the cursor to the left.

Help information for COED is provided by pressing the <**F1**> key where the Function keys are defined. A list of additional help information is also included, as shown in Figure 8. The COED User's Manual is essentially provided through the help file.

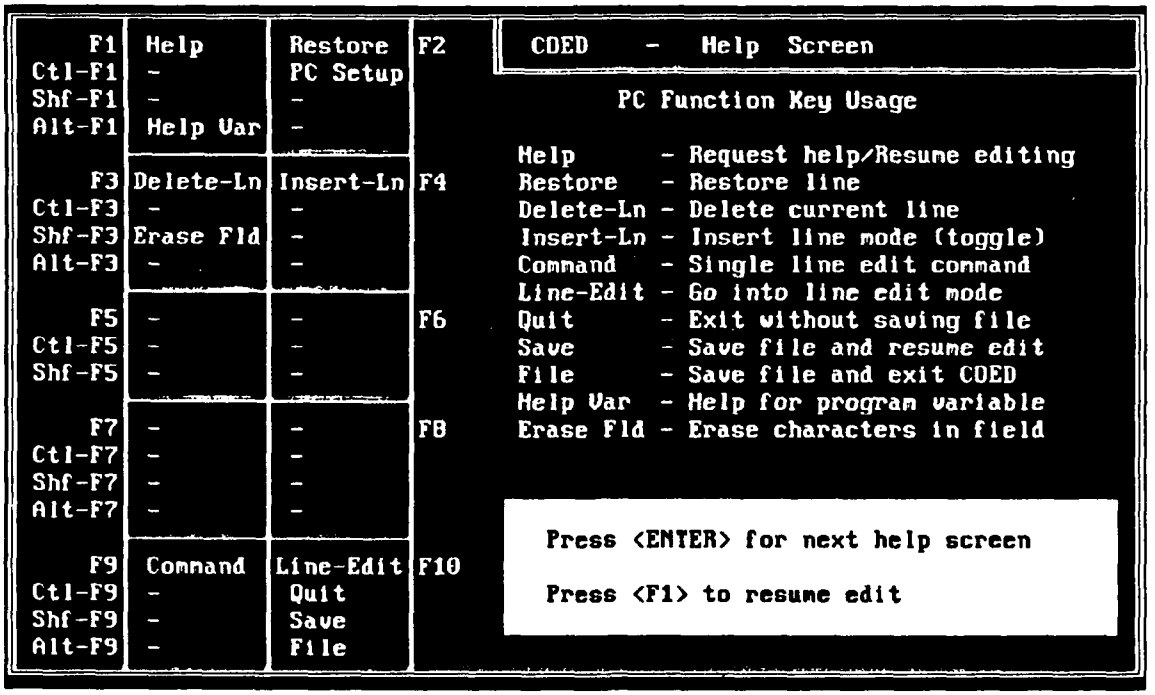

Figure 8. COED Help File Screen

Help information for HEC-5 variables is provided by pressing **<ALT> <F1>**. The HEC-5 ID in columns one and two provides the line of variables, for that record type, shown at the bottom of the screen. Moving the cursor to any field on the data input line and pressing **<ALT> <F1>** provides the input description for that field's variable. Therefore, while you are entering data, you can obtain the input description for any input variable in the HEC-5 program.

With the HEC-5 help file loaded, COED can recognize legal input types. That is, the program does not accept a letter "O" for an entry that requires a numeric "0". This feature should reduce illegal input data errors.

4.6 INFIVE Application

INFIVE is an interactive program that generates an HEC-5 input file by asking the user a series of questions about the reservoir system. The input file created by the program contains all the records needed for the simulation in the proper sequence, but does not fill in all the data on the records. INFIVE also provides variable names describing record fields that need to be filled in by the user. A thorough description of the INFIVE program can be found in the INFIVE User's Manual.

An appropriate use of INFIVE is to create the input file containing the records in the correct sequence, then use COED to enter the input data.

4.7 INCARD Application

INCARD is a separate program that converts continuous time series data input into different time intervals in the HEC-5 format. For example, daily flow data can be automatically converted to average monthly data for use in a monthly HEC-5 simulation. Input to the program is HEC-5 format time series data (BF to ER records). A complete description of capabilities and input and output formats is in the INCARD User's Manual.

Chapter 5

Checking an Input File for Errors

Once an input data file has been developed, the data should be checked for format errors and possible input errors. The HEC-5 program provides input data checks; but if there is a fatal error, the program stops. If there were several fatal data errors, it would require several attempts with HEC-5 before each one was found. Therefore, the input data file should first be checked with the CKHEC5 program.

5.1 Purpose of CKHEC5 Program

The CKHEC5 program processes an entire HEC-5 input data file and provides a list of all the data errors found. Physical, operational and hydrologic data are checked for proper format and for a proper range of values. The only records not checked are those containing only alphanumeric data (i.e. Title records and ID record), and the ZR and ZW records. Although the program does not distinguish between fatal and non-fatal errors, it does identify data inconsistencies and possible input errors through caution messages. It most cases it is strongly advised that the data be changed when a caution message is given. The HEC-5 program is more forgiving than the CKHEC5 program; therefore possible errors detected by CKHEC5 may not be noted by HEC-5.

Please review the CKHEC5 User's Manual for a complete description of the program, the types of checks performed, an input/output summary and example outputs of several data files run through CKHEC5.

5.2 CKHEC5 Program Execution

The CKHEC5 program can be conveniently run from MENU5. Move the cursor to highlight option 3., then press the <Space Bar> until the line indicates **RUN CKHEC5**, and then press **<ENTER>**.

The CKHEC5 program uses the HEC-5 input data file as its input; no additional input is required. For the check program to be able to read and properly check the data records, Field 1 (control point number) of the RL record and CP records must be correct and the RL record must precede all data for that reservoir. Likewise, the CP record must precede all non-reservoir data for that location. If these basic rules are followed, then the check program should be able to make a useful check.

The HEC-5 input data listing and error messages are written to an output file with an extension of .CK5. When CKHEC5 is finished, program **LIST** is invoked for reviewing the results from CKHEC5. If there are error messages, you can print them from LIST by turning on the Print Option **<P>**. The screen display is then be sent to the printer. The entire output file can be sent to the printer from MENU5 by highlighting Option 4 and by pressing the space bar to toggle to **4. Display output to printer** and pressing **<ENTER>**. You then need to specify the file to be printed as "filename".**CK5**.

To execute CKHEC5 as a separate program, at the DOS prompt enter:

CKHEC5 INPUT= "filename" **OUTPUT=**"filename"

where: "filename" = the input and output file names.

For example: **CKHEC5 INPUT=ST1.DAT OUTPUT=ST1CK5.OUT**

where ST1.DAT is the input data file to be checked and ST1CK5.OUT is the output file containing the messages from Program CKHEC5.

This execution procedure assumes that the data is in your current directory. Otherwise, also indicate the proper drive and directory for the data. If the input and/or output file names are not given, the program requests the name of the file. In response, enter the appropriate input and output file names.

5.3 Types of Data Checks Performed

Three general types of data checks are performed:

1. Checks for complete records, e.g., all records are present and in required order

2. Checks for specified record fields, e.g., integer check, check for data within specified numerical values, check for exact numeric values and check for valid sequence of control point numbers.

3. Special record checks, e.g., job record checks and time series data checks.

5.4 Error Messages Provided

The program provides numerous checks, and the messages are, hopefully, complete enough to focus the user on the source of the problem. There is no separate list of error checks and messages. The user must interpret the information based on the input data. If some messages do not make sense, correct the ones that do and check the data again. A CKHEC5 execution is a fraction of the time of an HEC-5 execution; it is therefore strongly recommended that the input file be checked with CKHEC5 prior to an HEC-5 execution.

The first information given in the CKHEC5 output file is the input data with line numbers printed to the left of each record. These line numbers are used to identify the exact location of the possible error. The general format for the messages is: **CAUTION-POSSIBLE DATA PROBLEM**. The line number where the problem occurs is then printed, along with the record type, the field and the given value: e.g., **LINE= 5 CARD= J2 FIELD= 2 VALUE= 1.00**. Then a description of the problem is given: **DATA OUTSIDE RANGE OF 1.10 2.00**. The user must then decide if this is indeed a real data error or if this data is what the user wants. (Note: this example of a caution message for the J2 record, field 2, often appears and depending on the user's application, may not be a real error message.) Often the message focuses on the variable that appears to be the problem source. If you are not familiar with the variable, refer to the HEC-5 Input Description in Exhibit 8 of the User's Manual. Review the record description, variable definition and input description. Usually the variable description is sufficient to understand the error message.

5.5 Correcting Input Data Errors

When **CARD OUT OF ORDER** or **INVALID ID-CARD NO.** or **REQUIRED CARD OUT OF ORDER OR MISSING** messages occur, many subsequent error messages may be generated. The **CARD OUT OF ORDER** error messages should be dealt with first. If in doubt about record order, refer to the foldout page at the end of the HEC-5 User's Manual, Exhibit 8. This "Summary of Input Cards" shows the records in their relative order of input. Carefully review your input file, and arrange the record sequence to follow the sequence shown in the Summary.

After correcting the input order, recheck the data file with CKHEC5. If there are error messages, try to correct the errors. There may be some messages that are given even when you have the data set the way you want it. Be sure you understand why your data are causing the message. If the data are the way you want them, go ahead and run the data with HEC-5.

Chapter 6

Simulation of Reservoir Systems

6.1 HEC5A and HEC5B Program Execution

This is the normal execution sequence for the majority of HEC-5 applications. In this mode, the operations portion of HEC-5 is executed first (HEC5A). An echo of the input data along with other program designed information is then written to the specified output file. This portion of the program also writes simulation results to DSS files (if requested) as well as to two intermediate files (Tape 17 and Tape 18) to be subsequently read by program HEC5B. The output portion of HEC-5 is executed second (HEC5B). This portion reads the intermediate files and creates various output tables as specified on the J8 and JZ records, and other output summary tables and printer plots as requested on the J3 record, fields 1 and 3. The output created by HEC5B is appended to the HEC5A output to form one continuous output file with the extension ".OUT".

As HEC5A simulates the reservoir system operation, it displays messages to the screen. A message is printed out each 10 time periods as shown in Figure 9. These messages are written to the screen so you know how far your job has progressed.

```
                    HEC5-A VERSION:      JANUARY 1989

                     PC IMPLEMENTATION:   17 JAN 1990
                       ("OVERLAYED" DOS 640K VERSION)

 ----------------------------------------------
 |                                            |
 |  *     *  *******  *******     *******     |
 |  *     *  *        *           *           |
 |  *******  ****     *       --- ******      |
 |  *     *  *        *                 *     |
 |  *     *  *******  *******     ******      |
 |                                            |
 ----------------------------------------------
     DATE: 02/28/90        TIME: 11:36:35


FLOOD:  1   PERIOD:  10   DATE:  02/28/90   TIME:  11:37:10
FLOOD:  1   PERIOD:  20   DATE:  02/28/90   TIME:  11:37:27
```

Figure 9. HEC5A Normal Execution

When HEC5A is complete, a screen comes up indicating that HEC5B is now executing. When HEC5B is complete, the following message is displayed:

Strike a key when ready...

6.2 HEC5A Execution Only

Many of the variables that are tabulated by HEC5B are also available directly from HEC5A. This option of executing only the "A" part can save substantial clock time for a large system of reservoirs or for long period of record simulations. In order to get user defined output from HEC5A, J3.9 must = 1 to suppress HEC5B execution. This option does limit certain output capabilities of the program and therefore should not be used if the following output options are needed:

Normal sequential output
Damage calculations
Frequency plots
Some power variables (see HEC-5 User's Manual Exhibit 8 for specifics regarding power variables).
To initiate execution of HEC5A "only", toggle option 3 shown on the main menu of MENU5 until "**Run HEC5 (A only)**" is highlighted.

6.3 HEC5A Interactive Execution

The interactive execution mode allows the user to review simulation results during HEC5A execution. The purposes of interactive output routines in HEC-5 are (1) to look at results quickly and efficiently (while stored in memory), (2) to look at output variables not requested by the input model, and (3) to reduce run times.

Simulation results can be reviewed in tabular or graphical form during interactive executions. This is accomplished through a series of menus.

To initiate an interactive HEC-5 execution while in MENU5, highlight "**Run HEC-5 (Interactive)**" from Option 3 of the main menu. The output file that is created during this interactive execution has the extension of **.TMP** instead of the typical extension of **.OUT**. This is done primarily to prevent overwriting an existing file that contains the results from a previous "batch" execution. As the interactive execution proceeds, several messages appear regarding the program's status. When HEC-5 has been loaded, the first message says, "**WELCOME to Program HEC-5...**" and "**Reservoir Simulation has begun:**" (Figure 10).

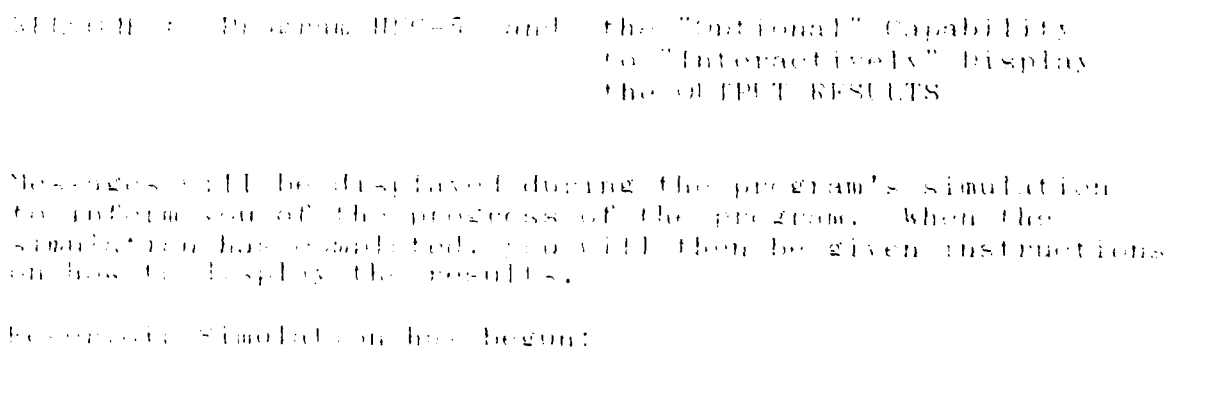

Figure 10. Interactive HEC-5: Main Screen

During simulation, an arrow traverses across the screen which indicates "% Periods Computed". Following the completion of the simulation, a series of menus is displayed from which output options can be selected to analyze the results.

The first menu is the "**HEC-5 OUTPUT MENU**", which offers the selections shown in Figure 11.

```
****************************************
*            HEC-5 OUTPUT MENU         *
****************************************

U -  USER Designed Output

P -  PROGRAM Designed Output

T -  TIME Window Specifications

O -  OUTPUT Size (Page length and width)

X -  EXIT  Menu


----------------------
Type LETTER of Option:
```

Figure 11. Interactive HEC-5: HEC-5 Output Menu

If you enter a <**P**> for "**PROGRAM Designed Output**" you will see other selections that can be made as shown in **Figure 12.** This menu provides an opportunity to review standard output on the screen. From this menu, enter an <**S**> to select the "**SUMMARY of MAXIMUM Events**". It is recommended that these summary tables be reviewed prior to the selection of other types of output. This summary shows the maximum inflow, outflow, storage, elevation, and level for each reservoir. Following the reservoir tabulation, a second table showing channel capacity, maximum regulated flow, discharge from upstream reservoirs, maximum cumulative local flow, and maximum natural flow for each control point in the basin is displayed. Since the tables are several screens long, the <ENTER> key must be pressed to advance through the entire summary.

After the summary tables have been displayed, the "**PROGRAM DESIGNED OUTPUT MENU**" is displayed again. You may wish to continue reviewing results by selecting the other options that are shown in Figure 12. When this review is complete, enter <**X**> to exit and return to the "**HEC-5 OUTPUT MENU**".

```
*****************************************
*      PROGRAM DESIGNED OUTPUT MENU     *
*****************************************

S -  SUMMARY of MAXIMUM Events

F -  FLOWS  (Regulated)  by Time Period

R -  RESERVOIR Variables by Time Period

E -  ERROR Check Messages

C -  CASE Codes for Reservoir Decisions

X -  EXIT to Previous Menu


----------------------
Type LETTER of Option:
```

Figure 12. Interactive HEC-5: Program Designed Output Menu

If you then enter <**U**> to select the "**USER Designed Output**", you may choose from a list of options as shown in Figure 13. From this menu you may wish to enter <**S**> to choose "**SELECT Output Variables and Locations**". This will access the display that is shown in Figure 14 where you are able to "interactively" design tables of data in the form of "side-by-side" columns displayed by time period. After you enter the items and locations that you desire, a "submenu" offers two options for displaying these selected items: T (for Tables) and P (for Plots). If you enter <**T**>, tabular columns are shown which are similar in format to the type of output that is created by the J8 records. If you enter <**P**>, then the items you selected are stored to your DSS file. See Figure 15 for further explanation for requesting plots during interactive executions of HEC-5 on the PC. After reviewing results from this menu, enter <**X**> to return to the "**USER DESIGNED OUTPUT MENU**".

```
****************************************
*       USER DESIGNED OUTPUT MENU      *
****************************************

S -  SELECT Output Variables and Locations

D -  DSS PLOTS from Pre-Defined Menu File

J -  J8/JZ  Output Variables and Locations

M -  MAP of System

X -  EXIT to Previous Menu


----------------------
Type LETTER of Option:S
```

Figure 13. Interactive HEC-5: User Designed Output Menu

```
********************  SELECTION  OF  OUTPUT  VARIABLES  ********************

   Group                    Reservoir Output
        RES =    *      2      1      3
     A       OUTFLOW       CASE          LEVEL
     B       INFLOW        OUTFLOW       CASE           LEVEL       EOP STG
     C       TOP CON STG   % FC STG      GATE REG REL   ELEV        TOP CON ELEV

                        Control Point Output
        LOC =    *      2      1      3      5      4      6
     G       CHANNEL CAP   REGULATED Q
     H       CHANNEL CAP   REG Q         Q SPACE        NATURAL Q   FLOOD GT LOC Q
     I       CUM LOCAL Q   INC LOCAL Q   U.S. RES/DIV
     J       DESIRED Q     DES Q SHOR    REGULATED Q
     K       REQUIRED Q    REQ Q SH
     L       DIVERS REQ    DIVERSION     DIVERSION SH

-----------------------------------------------
Enter your Request  ("or"  X to EXIT,  ? for HELP)
3 B
```

Figure 14. Interactive HEC-5: Select Output Variables and Locations

IMPORTANT

DSPLAY can be executed **only** from the main HEC-5 Package Menu, Option 3, "**Run DSPLAY**". DSPLAY cannot be run directly from any of the Interactive HEC-5 Menus, or through MOD5. The Interactive HEC-5 Menus and MOD5 Menus will store the DSS data as required and then will return to the current menu of the program being executed (these programs cannot chain directly to DSPLAY). To get graphical displays, exit these programs, return to the main HEC-5 Package Menu and then select Run DSPLAY. Refer to Chapter 9, Plotting with DSPLAY and the HECDSS User's Manual for more information on the use of DSPLAY.

Figure 15. Interactive HEC-5: Requesting Plots

The next option of output review refers to "**DSS PLOTS from Pre-Defined Menu File**". If you enter <**D**> the results are stored in DSS for those items specified on the input JZ records. For execution on the PC, this option writes to the DSS file which can later be accessed by program DSPLAY from the HEC-5 Package Menu Option 3 for getting graphical plots.

Also available from the "**USER DESIGNED OUTPUT MENU**" screen, if you enter <**M**> a schematic map showing the relative location of reservoirs and non-reservoir control points (as well as the HEC-5 location numbers) is created.

After interactively reviewing the simulation results, you may wish to rerun the HEC-5 simulation with a change in operational parameters at one or more of the reservoirs. This can be accomplished through program MOD5. Before you can initiate program MOD5, exit the HEC-5 program. You can enter an <**X**> at each menu until the "**EXIT HEC5 MENU**" is displayed as shown in Figure 16.

```
*****************************************
*          EXIT  HEC-5  MENU            *
*****************************************

S -  SAVE   HEC-5 Simulation Results to
                 Output File  and  DSS

Q -  QUIT   Program HEC5A Execution

X -  EXIT   to Previous Menu

----------------------
Type LETTER of Option:
```

Figure 16. Interactive HEC-5: Exit HEC-5 Menu

The "**EXIT HEC-5 MENU**" menu basically gives you two options for concluding the HEC-5 interactive execution. If you enter <**S**>, then the simulation results are "saved" into your output file (has the extension of .TMP) and contains the tables of items that were specified on the J8 records in your input file. Also, your DSS file is updated to include the results for those items specified on the JZ records in your input file. However, if you are not interested in saving the results, you may enter <**Q**> to "quit" HEC-5 execution. A note is displayed reminding you that the results of this execution is not saved. Upon selection of either of these two options, you will exit program HEC-5 and return back to the HEC-5 Package Menu (MENU5).

At this point, you can execute program MOD5 using option 2. "**Create/edit input file...**". Use the space bar to toggle to "**MOD5**". Press <**ENTER**> to display the MOD5 "**MAIN Menu**" which offers editing options as shown in Figure 17. Please refer to Chapter 8 and the MOD5 User's Manual for further discussion on the use of MOD5.

```
(MAIN Menu)   Options for  MODIFYING  HEC-5  INPUT File          (MENU 1)
OCTOBER 1989  Version:    Max time periods allowed = 300

G   GENERAL Operational Data  (for ALL Locations)  (J1-JR)     (M-9)

P   PHYSICAL    Data          (Each Location)      (RL-ED)     (M-15)

H   HYDROLOGIC  Data          (Time Series)        (IN-ER)     (M-16)

M   MAP      (SCHEMATIC of System)

R   RESERVOIR Operational Criteria    (for Each Reservoir)     (M-3)

O   OUTPUT    for Batch Job                (J3,J8,JZ cards)    (M-6)

T   TITLE  Information for Model             (T1-T3 cards)    (M-12)

X   EXIT   Menu  (Save File / Quit)                            (M-5)
-------------------------------------------------------------------
Type LETTER of Option to be selected:
```

Figure 17. MOD5 Main Menu

6.4 Command Line Mode

While the MENU5 program is the recommended method to execute HEC-5, you can run the program without using the menu. To run the program directly from DOS, do the following:

* Go to the directory where your data is stored (e.g., \HEC5)

* Type **H5A** then press the **<ENTER>** key.

1. The program responds with a banner page and **ENTER INPUT FILENAME**. In response to the request for an input filename, enter your input file name (e.g., **ST1.DAT**)

2. After entering the input filename, the program then responds with **ENTER OUTPUT FILENAME**. It is suggested that you enter an output filename (i.e., **ST1.OUT**). However, you may enter PRN if you wish to send the output directly to the printer (not advisable since output can be quite extensive); or, CON, if you wish the output to be displayed on the console (also not advisable since output scrolls off the screen).

3. After entering the output filename, the program responds with **ENTER DSS FILENAME**. At this point a DSS filename should be entered if the input data set uses JZ, ZR, or ZW records. If the DSS capability is not being utilized, the user should press the **<ENTER>** key to initiate the simulation.

4. When the simulation part of HEC-5 (HEC5A) has been completed, the console displays a DOS prompt. Respond to this prompt with **H5B** if you wish to execute the output portion (HEC5B). In response to **ENTER OUTPUT FILENAME** enter the output filename used in Step 2. Although HEC5B is normally utilized to create output tables and plots, some output capabilities have been added to HEC5A (see Section 6.2 of this document and J3.9 in HEC-5 Exhibit 8).

6.5 HEC5 Batch Mode Execution

6.5.1 Basic Mode

To execute both parts of program HEC-5 (HEC5A and HEC5B) in a batch mode, use an editor to create a "BAT" file (e.g., RUNHEC5.BAT) that contains the following commands:

```
H5A,INPUT=%1.DAT,OUTPUT=%1.OUT,DSS=%1.DSS
H5B,OUTPUT=%1.OUT
```

You can then run the program by entering:

```
RUNHEC5 ST1
```

Note: **"ST1"** replaces all the "%1" in the Batch file.

6.5.2 Options

Four options are available on the H5A execution line in batch mode. The options are as follows:

1. **DSSIN=MASTER.DSS** — DSS Master file where more permanent data is stored. DSS data read in on ZR records access this file. This file can have any name with the extension .DSS.

2. **DSSOUT=ST1.DSS** — DSS file where the simulation output variables requested by JZ and ZW records are written.

3. **MENU=ON** — Invokes the HEC-5 **interactive** output menu capabilities (see Section 6.3).

4. **QLOCINC=ST1.Q** — Read and write incremental local flows to a binary file (J3.6 must be coded with a 5 or 16 to invoke this option

The following is an example of an interactive HEC-5 execution using three of the optional specifications:

H5A,IN=ST1.DAT,OUT=ST1.OUT,DSSIN=MASTER.DSS,DSSOUT=ST1.DSS,MENU=ON

For this execution two DSS files (**MASTER.DSS** for input and **ST1.DSS** for output) are defined. The addition of **MENU=ON** to the execution line invokes interactive output option of HEC-5. Notice that in this example, **INPUT** and **OUTPUT** are abbreviated to **IN** and **OUT**, respectively. Allowable abbreviations for the HEC-5 programs may be determined by entering the program name followed by a space and a question mark (e.g., **H5A ?**).

6.6 Program Output Files

The output files created by HEC-5 are contained in the "**.OUT**" files. If both HEC5A and HEC5B were executed, the results from both are included in the "**OUT**" file. If HEC5A only were run, its results are also be found in the "**OUT**" file. Two intermediate binary files, TAPE17 and TAPE18 contain the HEC5A results which are read by HEC5B.

6.7 Use of HECDSS Files

In addition to the output files generated directly by HEC-5, simulation results for certain items can also be written to the HEC Data Storage System (HECDSS or just DSS). HEC developed DSS to manage time series data storage and retrieval needs for water resource studies. The system which has been under development since 1979, enables efficient storage and retrieval of time series and other data-types for which storage in blocks of contiguous data elements is most appropriate. The DSS consists of a library of routines and programs which can be readily used with applications programs like HEC-5 to enable retrival and storage of information. For additional information on DSS see "HECDSS, Overview and User's Guide".

In HEC-5 DSS output is controlled by JZ and ZW records and requested items are contained in the "**.DSS**" files. A different file can be used to read DSS data (a master DSS data bank) and to write DSS data. The master DSS file usually contains more permanent variables such as inflow data or incremental flow data. Simulation output data for a specific run can then be written to another DSS file. However, when using the HEC-5 Package Menu (MENU5) the assumption is made that you are reading from and writing to the same DSS file.

Several HECDSS utility programs are included in the HEC-5 Package. Programs DSSIN and DSSTS can be used to facilitate the input of time series data into a DSS file. Once the data is stored in DSS, program DSSUTL can be run to perform various tabulations and data manipulation. Refer to HECDSS User's Guide for further explanation of DSSUTL. Plots and tables can also be generated using data stored in DSS through execution of another utility program called DSPLAY (see Section 9).

6.8 Temporary Files Associated with the HEC-5 Program

Program HEC-5 is actually two separate programs (HEC5A and HEC5B) that are linked by intermediate files and executed in sequential order as one job. The first program reads input and simulates reservoir operation. The second program reads the intermediate files and creates output displays and performs the economic analysis. Certain applications require only the first program; most require both.

Besides INPUT, OUTPUT and DSS files, up to 12 files may be created or used in an HEC-5 application. Tape 17 and Tape 18 are intermediate binary files between HEC5A and HEC5B. The remaining files are "scratch files" (i.e. **SCRATCH.xxx**) and are deleted when the program terminates normally. If the program terminates abnormally, the SCRATCH files should be removed with the DOS DEL command.

Chapter 7

Reviewing the HEC-5 Output File

7.1 Reviewing the Program Output File with Program LIST

The LIST program is a public domain utility that provides a convenient way of viewing text (ASCII) files on the screen. It has the advantage of allowing you to shift your view of the output from left to right, as well as up and down. Because the standard output file from HEC-5 is 132 characters wide, the ability to shift your view of the output file in all four directions makes it easy to scan an entire output file on an 80-character screen.

The program uses the cursor control keys in a logical manner. **Page Up** and **Page Down** keys move you up and down though the file in screen blocks of text. **Up** and **Down Arrow** keys move you one line at a time. **Left** and **Right Arrows** shift the text left and right 20 columns. **Home** and **End** keys move you to the beginning and to the end of the file.

Help is called with the <**F1**> key or a question mark <**?**>. The Help file list includes the commands and the control keys to call the commands. Often several logical choices of control keys are used to call a command. The escape key <**Esc**>, as well as the letters <**Q**> and <**X**>, terminates the program.

MENU5 calls LIST when you select **4. Display output to console**. To execute LIST as a separate program, from the DOS prompt enter:

List "*filename*" *(also enter: Drive: and \pathname\ if required)*

If you don't include the "filename", the program responds:

Enter filename:

Input the file name, and the program displays the first block of text in the file. Also, there is a partial list of program commands shown at the bottom of the screen. The program makes it easy to view the output file on the screen. There is also a print on/off switch, invoked by pressing the letter <**P**>, which sends the viewed output to the printer. This feature makes it easy to print selected portions of the output file.

7.2 Output Sequence

The output to be provided for a given job is based on the input item J3.1 and the variables requested on the J8 records. Each output table is labeled with a single descriptive word or variable beginning with a "*". The sequence of possible output from the program, depending upon options used and output requested, is:

(1) Printout of input data (*INPUT, *FLOWS, *INTAB, and *RTCOF)

(2) Computation of incremental local flows (*LOCFL)

(3) Printout of optimization trials and summary (*OPTRY and *OPSUM)

(4) Results of all variables defined and requested by input data for the system operations arranged by downstream sequence of control points (*NORML)

(5) Reservoir operation summary and control point summary arranged by sequence of time periods (*ROPER)

(6) Summary of releases from reservoirs and actual flow at all other control points, arranged by period (*RRPER and *RQPER)

(7) User defined output based on J8 record input (*USERS)

(8) Plotted hydrographs at specified control points (*PLOTS)

(9) Summary of flooding occurring during each flood event (*SUMF1)

(10) Flood event summaries for multiflood events (*SUMFS and *SUMPO)

(11) Economic input data and damage computation (*ECDAM)

(12) Flood frequency plots (*EPLOT)

(13) Summary of damages or average annual damages, system costs and net benefits (*ESUMD, *ESUMC, and *ESUMB)

(14) Summary of discharge and stage reduction at each non-reservoir control point for each flood event (*HYEFF)

(15) Computer check for possible errors (*ERROR),

(16) Listing of case designation defining reservoir releases (*CASES)

Exhibit 7 of the HEC-5 User's Manual provides a more detailed description of these output groups.

7.3 Output Review

Generally, the User Requested Summary Tables (J8 records) are the first place to review output. To access these tables through LIST, use the search command to find ***USER**, (e.g., F *USER). This takes you directly to the first user requested summary table. From here, the **<Page Down>** key can be used to scroll through the table. To review the next table, the search command can again be used to find ***USER** by pressing the **<F3>** key.

A second important table to review is ***INTAB**, the printout of input data. This should be reviewed to insure that the data used by the program is what the user intended. The computer check for possible errors should also be reviewed by searching for ***ERROR**. During the final portion of the HEC5A execution, simulation results of the program operation are checked for possible reservoir operation errors. If a constraint is violated, an error message is printed in the output file, if requested by the user (see J3.1 = 4). There are six possible error messages that may be printed in this table:

(1) "MINIMUM FLOW NOT SUPPLIED" The desired or required flow at the current control point was not satisfied and one or more reservoirs had storage that could have reduced or eliminated the shortage. This message is followed by the following diagnostic statement:

POSSIBLE ERROR, CP=___, IP=___, ACT Q=___, CCAP=____, RES NO=___, LEVEL=___, ABOVE LEVEL___, REL=___, PER=___

This indicates that a possible error was found at a control point CP for time period IP. The actual flow (ACT Q) is listed for the indicated control point and time period. The control point's minimum desired or required flow (CCAP) is also shown. (Note that the program may be revised in the future to change the label of CCAP to MINQ.) The last five items identify the reservoir (RES NO) that was the source of the possible erroneous release, the level of the reservoir at the end or that period (LEVEL) and the next lower integer level (ABOVE LEVEL), the release (REL) that was made and the period (PER) in which the release was made.

(2) "FLOODING CAUSED BY RESERVOIR" Flooding at the current control point was caused at least in part by nonessential releases from an upstream reservoir. This message is followed by the following diagnostic statement:

POSSIBLE ERROR, CP=___, IP=___, ACT Q=___, MINQ=____, RES NO=___, LEVEL=___, ABOVE LEVEL___, REL=___, PER=___

This indicates that a possible error was found at a control point CP for time period IP. The actual flow (ACT Q) and the control point's channel capacity (MINQ) are also shown. (Note that the program may be revised in the future to change the label of MINQ to CCAP.) The last five items identify the reservoir (RES NO) that was the source of the possible erroneous release, the level of the reservoir at the end or that period (LEVEL) and the next lower integer level (ABOVE LEVEL), the release (REL) that was made and the period (PER) in which the release was made.

(3) "RESERVOIR RELEASE INCORRECTLY BASED ON D.S. FLOW" This message is followed by the following diagnostic statement:

POSSIBLE ERROR, RES NO=___, PER=___, CASE=___, LEVEL=___, D.S.FLOW=___, REL=___, CC=___

This indicates that the downstream flow is not the same as the target flow (which is either a low flow requirement or operational channel capacity value). The possible error is caused by the operation of the reservoir (RES NO) during a specific time period (PER). The downstream location is reflected in CASE as the number to the left of the decimal point. Refer to the reservoir level (LEVEL) to see if the reservoir is in flood control or conservation pool. If the reservoir is in flood control operation, then the target flow is the downstream channel capacity. If the reservoir is in conservation operation, then the target flow is the downstream minimum desired or required flow. In either situation, the actual downstream flow (D.S. FLOW) should be within a five percent tolerance of the target flow (which has been adjusted to reflect the contingency factor supplied in field 2 of the J2 record). The reservoir release (REL) is also shown as well as the downstream channel capacity (CC).

(4) "RESERVOIR CASE OR RELEASE ERROR" This message indicates that the reservoir release (REL) does not correspond with the "reason" (CASE) for making that release. The reservoir number, period, case, level, downstream flow, release, and channel capacity are displayed as:

RES NO=___, PER=___, CASE=___, LEVEL=___, D.S.FLOW=___, REL=___, CC=___

(5) "RATE/CHANGE ERROR" This message indicates a rate of change constraint has been violated. The reservoir number, period, actual rate of change during that period, and allowable rate of change for rising and falling discharges are displayed as:

RS=___, PER=___, RATE/CHANGE=___, ALLOWED R/C-RIS=___, ALLOWED R/C-FAL=___

(6) "ERROR - RESERVOIR CHANGE OF STORAGE NOT EQUAL TO INFLOW-OUTFLOW, RES =____, PERIOD=____". This message indicates that mass continuity has not been maintained for the reservoir and time period shown.

When reviewing possible error messages, it is useful to look at the table of cases, located at the end of the output. Using LIST, search for ***CASES** to access this table.

The output tables given in an HEC-5 output file depend upon the options used in simulation and the output requested by the user. Other output tables can be viewed using LIST by searching for the single descriptive word or variable used for the table heading. These always begin with an asterisk (*****) and are shown in Exhibit 7 of the HEC-5 User's Manual.

7.4 Important Simulation Variables

In Section 4.4, a list of recommended output variables was given in order to properly review reservoir operations. In reviewing your simulation results, special attention should be paid to these variables. In periods where a minimum flow requirement is not met, the reservoir case variable and the reservoir level should provide insight as to why the shortage occurred. Is the reservoir out of water? Or is there a conflict in operational priorities? The level tells you not only how much water is remaining in the reservoir, but also indicates the operating "zone". Different operational rules apply between different levels, or zones. The reason a release was made is explained by the "case" variable.

In hydropower studies, any shortages in energy generation should be explained. Likewise, in periods where flooding is occurring in the system, the reservoir case and level (as well as the channel capacity at the downstream controlling location) should be reviewed to explain the reservoir operation. To facilitate a thorough output review, it is recommended that program users become familiar with the J8 and JZ records and request the important simulation output variables noted in Section 4.4.

Chapter 8

Modifying Input with MOD5

8.1 Purpose of MOD5 Program

The purpose of program MOD5 is to provide a menu driven program which allows new and occasional users to modify existing HEC-5 data files easily. For real-time applications, MOD5 provides an easy means for the user to override HEC-5 determined releases and to modify operational criteria. For a complete description of MOD5's capabilities and usage, and some sample displays, refer to the MOD5 User's Manual. The remainder of this section is a brief summary of how to use MOD5 from the MENU5 shell.

8.2 MOD5 Program Execution

To use MOD5, a HEC-5 input data set must first be created using either COED or INFIVE and COED together. To invoke MOD5, use the space bar to toggle Menu Option 2 until "**Run MOD5**" appears. MOD5 then displays menus which allow you to make modifications to the current input data interactively (see Figure 17). Help information is available for most menu options.

MOD5 displays menus and tables of data describing the HEC-5 input data for your system. At the conclusion of the editing session a new input file for HEC-5 is created if requested. This new input file for HEC-5 is the output from MOD5. The input file can then be executed using any of the options described in Section 6. No other output is available from MOD5 unless trace data is requested.

8.3 Modifying Data

Through a series of menus and submenus, the following primary types of system input data can be modified by MOD5:

* General data:	Data dealing with operational criteria applicable to all locations
* Physical data:	Reservoir storage allocation Reservoir Area/Storage/Capacity/Elevation Channel Capacities Low Flow Requirements Routing Criteria
* Hydrologic data:	Inflows, outflows, and channel capacities and rule curves which vary with time

8.4 Modifying HEC-5 Output

In addition to modifying the system operational characteristics, MOD5 through a series of menu choices can help the HEC-5 user select HEC-5 output options. HEC-5 J3, J8 and JZ records may be edited, displayed or new J8 or JZ records may be created. The J3 record allows the user to select from many of the output tables described in Section 7.2. The J8 and JZ records may be used to create user defined output tables using the output variables described in Sections 4.4 and 7.4.

Chapter 9

Plotting with DSPLAY

9.1 Purpose of DSPLAY Program

The HEC Data Storage System (HECDSS) is a data base primarily designed to store time series data commonly used in water resource applications. HECDSS stores data in a form that is convenient for inventory, retrieval, archiving and model use. In addition to use by application programs, a set of supporting utility programs allow entry, editing and display of information.

The HECDSS DSPLAY Module is a utility program whose main function is the provide a quick and simple means of displaying data stored in HECDSS files. Two types of displays are available to the user, a graphical display and a tabular display.

9.2 DSPLAY Program Execution

The DSPLAY graphics program included in the HEC-5 Package uses "drivers" that provide a means for generating graphical displays on different devices (monitors, plotters, printers, etc.). These drivers are distributed by Graphics Software Systems, Inc. (GSS), 9590 S.W. Gemini Drive, Beaverton, OR 97005. This software is proprietary. HEC has accquired licenses for Corps offices; all others should obtain the required drivers directly from GSS or from software retail stores.

Before running DSPLAY, the GSS drivers must be loaded into memory, which is done by the DRIVERS program. To automate the process a small batch file, DSP.BAT is included in the DSPLAY.ZIP file. DSPLAY and the device drivers require about 550Kb of memory and cannot be used with memory resident programs. If DSPLAY aborts with the "**Program too big to fit in memory**" error message, remove any memory resident programs and try again.

9.3 Output Devices

When running DSPLAY, an output device may be selected by the DEVICE command (the screen is the default). The devices which are used with DSPLAY must be installed and DEVICE statements for the appropriate device drivers must be added to the CONFIG.SYS file. DSPLAY can use five different device types: monitors, printers, plotters, and mice. Refer to "Installation Instructions for Device Drivers", provided by HEC, for a complete list of GSS device drivers currently available and complete installation instructions.

9.4 Time Series Data Plots

Once data is stored in a DSS file, DSPLAY can be used to access that data and plot graphs of data the user wishes to display. Data is retrieved from the DSS file by specifying the pathname (or pathname number) of the data the user wishes to display.

A listing of pathnames and corresponding pathname numbers for a specific DSS file may be generated by using the DSPLAY "catalog" command. The catalog command in the form "**CA.NA**" will create a (**N**ew, **A**bbreviated) listing in a form appropriate for on screen viewing. DSS catalog files may be directed

to a printer while in DSPLAY with the catalog command "**CA.NPS**" (**N**ew, **P**rinter and **S**uppress display of catalog on screen). DSS catalog files are labeled with the DOS extension "**.DSC**". DSSUTL may also be used to create catalogs as well as perform other DSS data management tasks.

The **Time** command can be used to define the starting and ending times of the data, if different than the implied block times. Up to seven curves can be plotted on one graph, and a plot can be split into upper and lower graphs for variables with different units. An example of a DSPLAY plot is given in Figure 18. The graph shows Standard Test 4 reservoir outflow and pool elevation written to DSS by the JZ and ZW records. The graph was produced by specifying the name of the DSS file, the pathnames for the data, and the time window. Graph scaling, labels and legends are automatic, unless redefined by the user. A detailed description of DSPLAY commands, options and use is included in the HECDSS User's Guide and Utility Program Manual, November 1987. Additionally, a summary of using program DSPLAY on the PC is contained in "Overview of DSPLAY for the PC". The capabilities of DSSUTL are described in "HECDSS, DSSUTL User's Manual".

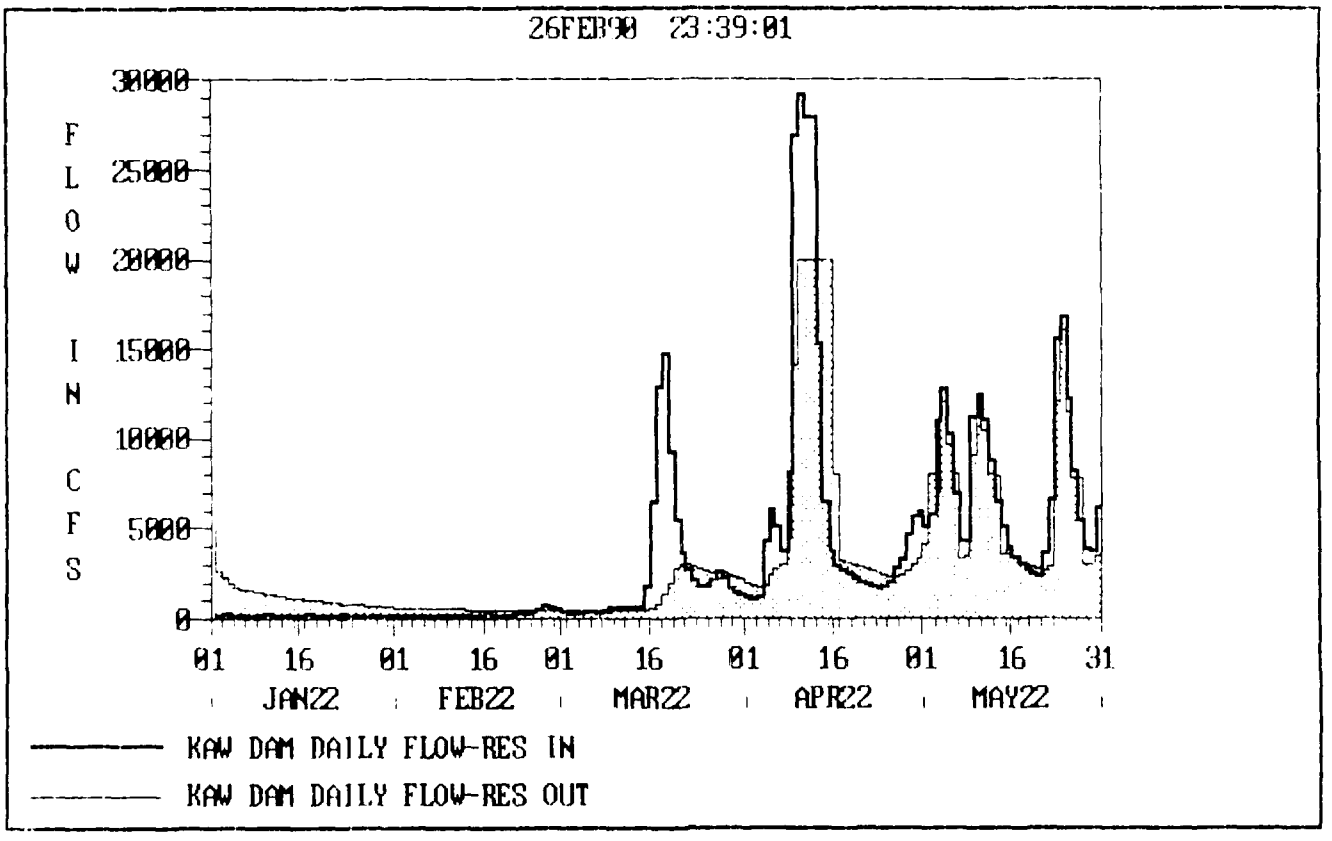

Figure 18. DSPLAY Plot of Standard Test 4 Simulation Results

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